FEASIBILITY OF ENTERPRISE FARMING ON THE HOPI RESERVATION USING FLOODWATER FOR IRRIGATION

by

Dennis Watt
and
Bill Green

U.S. BUREAU OF RECLAMATION

Lower Colorado Regional Office
Boulder City, Nevada

January 2002

main part of the Hopi Reservation. Of interest is the decrease in average annual flow over the last century. From 1926 to 1940, the average annual flow was 16,345 acre-feet (Navajo Nation Department of Water Resources). More recent flood runoff is much less. From 1977 through 1999, the average annual flow was only 6,584 acre-feet. Moenkopi Wash base flow, however, has remain essentially unchanged. The base flow in 1998, a low total runoff year, is about the same or slightly more than in 1977, a high total runoff year.

Tables 1 and 2 show monthly mean streamflow and the mean of daily mean values for Oraibi, Polacca, Dinnebito, and Jeddito Washes on the Hopi Reservation. Both Polacca Wash near Second Mesa and Dinnebito Wash near Sand Springs have small base flows at the gages. At each the base flow in the summer is less, presumably due to water consumption by phreatophytes. Flow in Jeddito and Oraibi Washes is flood runoff only.

Inspection of the monthly mean streamflow for the 7 full years of record at Jeddito shows that most of the flow is in July, August, September, and October, but several years show no flow in July and October. Even in August and September there are years with no flow. Each runoff event on Jeddito lasts only a few days with a large flow on the first day.

The monthly mean streamflow record for Oraibi Wash is generally the same as Jeddito. The monthly mean volume in the summer is larger on Oraibi because the watershed is larger. The general lack of runoff in May and June on Jeddito and Oraibi makes flood water farming unfeasible without carryover water storage from the previous year. Sediment load, as discussed below, makes storage uneconomical.

Sediment Load

Most streams in the Little Colorado River Basin carry large sediment loads. Although it is not know if sedimentation was a factor in the abandonment of the Jeddito and Dinnebito Projects mentioned below, it was likely a problem. Norton and Sandor (1997) note that soil eroded from Zuni lands has filled every impoundment built for irrigation, flood control, or erosion control, rendering them nearly useless and often causing washouts and further erosion of stream courses.

Andrews (1991) shows mean annual runoff and sediment load at selected stations in the Colorado River basin. Mean annual sediment load for the Little Colorado River at Cameron is 9.27 million tons per year, or about 355 tons per year per square mile. This is about 0.14 acre-feet of sediment per square mile, assuming one cubic foot of sediment weighs 120 pounds. The sediment production per unit area for all of the Little Colorado River basin is a little less than the lowest sediment production rate [0.20 acre-feet per square mile] shown by Hains and others (1952) for small drainage basins within the Little Colorado River basin. The likely lower average slope for the large Little Colorado River basin [26,091 square miles] probably accounts for the lower sediment production rate as compared to the small basins investigated by Hains and others (1952).

Applying the Little Colorado River basin mean annual sediment load per square mile to the

Oraibi Wash basin yields about 225,000 tons per year. Therefore, each acre-foot of Oraibi Wash flow carries about 141 tons of sediment based on a mean annual Oraibi Wash flow of about 1,600 acre-feet per year. This is about 87 cubic yards of sediment per acre-foot of water assuming one cubic foot of sediment weighs 120 pounds. Actual sediment production per unit of water in the 635 square mile Oraibi Wash basin is probably a little more than in the 26,000 square mile Little Colorado River basin.

FARMING IN HOPI COUNTRY

Traditional and Historic Hopi Farming

One of the reasons Hopi country is now inhabited by an agricultural people is because it lies in the local climate zone which is most suitable for agriculture (Hack, 1942). To the north, mean annual precipitation increases with elevation but the length of the growing season decreases. To the south, the growing season is longer but mean annual precipitation is less.

Average annual precipitation of only 11 or 12 inches, such as characterizes traditional Hopi farming country, is not sufficient to grow corn (or other crops) without special methods (Hack, 1942). Flood-water farming has been the dominant type of agriculture practiced by Hopi for centuries. Hack, a geologist with the Awatovi Archaeological Expedition of the Peabody Museum, described Hopi farming in the late 1930's. At that time, farming in Hopi country was still practiced as it had been for centuries.

Hack (1942) divided flood-water farming in northeast Arizona Indian country into four zones which depend entirely on climate.

> 1) Zone of no corn production and scant farms in which precipitation is over 16-18 inches, and the growing season is shorter than 110 to 120 days.
>
> 2) Zone of precarious flood-water farming in which precipitation is over 12 inches and less than 16 to 18 inches, and the growing season is longer than 120 days.
>
> 3) Main zone of flood-water farming (on small arroyos) in which precipitation is over 9-10 inches and less than 12 to 13 inches, and the growing season is adequate.
>
> 4) Lower zone of flood-water farming in desert regions (on main water courses), in which the rainfall is less than 9 inches, and the growing season is adequate. Farming in this zone is precarious because of the difficulty of protecting fields from powerful floods.

A U.S. Soil Conservation Service map shows that in 1937 the farm fields conform to this distribution. In District 6, the fields are relatively dense and they are located mostly at the ends of shallow arroyos. Few fields are show in District 5 to the south. Most of the District 5 fields shown along the Little Colorado River on the 1937 SCS map are near Leupp in a government planned irrigation project (Hack, 1942). This project was apparently abandoned many years ago since there is little evidence as seen from the air. Hack (1942) speculates that the Hopi, as the first comers, chose to inhabit the District 6 area because it is more favorable for agriculture than District 4 to the north or District 5 to the south.

The most common location for a flood-water field in Hopi country in the late 1930's was on an arroyo of intermediate size at its so-called mouth or at the place where there ceases to be a channel and the water spreads (Hack, 1942). In southern Arizona the arroyo mouth is sometimes called an "akchin," the Tohono Odom word for arroyo mouth (Bryan, 1929). The arroyo mouth is a favored place for the location of a field because the runoff of the entire arroyo watershed spreads out naturally over a relatively smooth surface without the aid of artificial spreading. In practice, the course of the floodwater across the field is in part controlled by the labor of the Hopi farmer who aids in spreading the water by digging channels to areas that are in danger of being left dry. Hack (1942) observed Hopi farmers out working in the fields during almost every flood of the growing season.

The arroyo mouth is not a fixed location because its position depends on the ratio of water velocity to the relative volume of debris carried (Hack, 1942). In one flood the critical point at which deposition occurs may be downstream from the similar point for another flood. The result is that the alluvial fan produced by one flood may be channeled by the next and a new fan will form below. Thus the favorable farming location is really an elongate area which may change its shape from one flood period to the next and may even move upstream or downstream (Hack, 1942). In practice, the Hopi farmer accommodated the sediment or debris load by moving the field with the movement of the arroyo mouth.

Hack (1942) noted that there seemed to be a fairly constant ratio in Hopi country between the size of the fields and the size of the watersheds which supplied them with water. Hack measured the field size and watershed size in 7 drainage basins. In these fields the area farmed is between 3 to 6 percent of the area of the whole drainage basin. Thus the ratio of field area to watershed area ranged from about 17 to 33. This is similar to the ratio noted by a more recent investigation of floodwater irrigation practiced thousands of years ago in the Negev Desert. Tadmor and others (1960) calculated the relative size of catchment areas and cultivated areas for 100 runoff farms. The ratio varied between 17 and 30, with an average of about 20.

Another common location for Hopi flood-water fields was along the course of a shallow arroyo where the water spreads over a wide area during a flood. Before the early 1900's arroyo cutting, many fields were located along the main washes. The Hopi at Oraibi are said to have farmed along Oraibi Wash by using berms and ditches which controlled the course of the floods (Hack, 1942). Thousands of years ago the same floodwater irrigation method was in use in the Negev Desert. The spreading method was abandoned in the Negev Desert, as in Hopi country, after downcutting transformed the wadi (desert wash) from a wide depression into a relatively narrow gravel-bed wadi (Evenari and others, 1982).

In the late 1930's most of the large arroyos in Hopi country had low but wide terraces in them which were usually about 10 to 15 feet above the stream bed. These terraces are overspread during all large floods and in lessor floods they are moistened by under seepage. These terraces were favored cornfield locations and many were seen in Oraibi Wash. These terraces have the disadvantage of being subject to destruction by violent floods (Hack, 1942).

Current Hopi Farming

Most of the recent and current farming in Hopi country appears to be what Hack (1942) calls sand dune agriculture. In the late 1930's, Hack (1942) noted that fields on bare sand areas were second in total farmed area to flood-water fields. Hack observed that most sand dune fields were underlain by a less pervious sub-soil. Typically the dune sand was one half to three feet thick. Dune sand underlain by less permeable soil is usable for farming because the sand absorbs all rainfall and it migrates downward and is perched on the shallow, less permeable sub-soil. The sand retains all rainfall whereas less porous surface soils cause some of the rainfall to run off.

Government Flood Water Farming Development History

Several surface water diversion structures were built in the first half of the twentieth century on or near the Hopi Reservation. The Dinnebito Wash, Hard Rocks, and Jeddito Wash diversion dams have since been destroyed by flood flows. Each diversion dam, except Hard Rocks, was built at the lower end of a short perennial flow reach (based on Cooley, 1969) but the irrigated acreage at each was mostly dependent on flood runoff.

The information in the following paragraphs was taken from the annual narrative summarys of BIA extension work found in the Northern Arizona University Library Special Collections. Only the Jeddito floodwater project is mentioned in the annual narratives since the Dinnebito and Hard Rocks projects were on Navajo lands. The narrative has some detail for 1940, the first year of planting, but there is little detail for the following years.

Flood runoff was intended to be the principal source of irrigation water for the Jeddito project. Jeddito Wash is the southernmost highlighted wash on Figure 1. Situated just outside the Hopi boundary at that time, the farming project adjacent to the wash was intended to support 11 families who would make their homes at the project. Another project, Phillips Farms, pumped apparently perennial water from springs rising in the bed of Polacca Wash to the bench just above and then into earthen ditches for distribution to gardens.

In 1940, the first year of operation, the Jeddito project was seeded to sudan grass which was disced in and seeded to winter rye in the fall. The Soil Conservation Service planted the field borders for wind erosion protection and fruit. The plantings included 481 grape vines, 20 apple trees, 23 apricot trees, 47 cherry trees, 22 pear trees, 207 raspberry vines, 201 blackberry vines, 48 gooseberry vines, and 12 current bushes.

In this first year of operation it became apparent that prospective settlers could not devote the necessary time on the project without neglecting their other farm holdings. The Jeddito tract itself did not offer large enough farm units to provide a living for a family without supplemental income from some other source. In addition, the tract must receive constant supervision in order to use the runoff water which can be expected to come at uncertain intervals.

In 1942, an exceptionally dry year, there was a shortage of water on both irrigated projects [Phillips Farms and Jeddito]. The Jeddito project was farmed by the Polacca Stockgrowers's

Association. They planted wheat and raised 25 tons of hay for feed.

During the war years there is little mention of the irrigation projects. The extension report for 1945 shows crops harvested and sale prices. In 1946, the extension report notes that nothing was accomplished except for a small repairs to dikes.

By 1949 it is apparent from the BIA annual extension summaries that the Jeddito project was abandoned. The annual extension report notes that "since there is no possibility of developing any practical or large scale irrigation projects on the Hopi Reservation, it would not be wise to attempt any drastic or over-all reforms in the agricultural practices of the Hopi people at this time."

A combination of factors probably caused the failure of the Jeddito irrigation project. First, as mentioned in the one of the annual extension reports, the Jeddito tracts were not large enough to provide a living for a family without supplemental income from some other source. This prevented full time occupancy which is need for runoff farming. Runoff farming requires constant supervision in order to use flood water which comes at uncertain intervals. Clearly, this is the reason traditional Hopi farmers lived on their runoff farming areas during the growing season. Second, modern stream gage records suggest that floodflow frequency is not sufficient for runoff farming. See the surface water runoff discussion above.

Kerley Valley Project on Moenkopi Wash
The diversion dam on Moenkopi Wash below Moenkopi appears to be a successful floodwater farming diversion but historical operational records indicate that most of the water diverted was late winter and early spring base flow. The Upper Kerley Valley (Moenkopi-Tuba) Irrigation Project is on land purchased by the federal government from Mormon settlers in 1903. The dam originally built by the Mormons was rebuilt by the federal government in 1909. After flood damage, the dam was improved in 1915, and again during 1921 through 1924 (Navajo Nation Department of Water Resources, 2000).

Table 3 shows historic Kerley Valley water diversions for 1949-1951. The comments clearly indicate that the water supply was good until late April. From late April through the summer, the diversion gradually drops to zero or near zero. During the summer the water supply was generally poor with flash floods depositing silt[2].

Figures 2 through 3 show graphs of Moenkopi Wash daily mean streamflow from March to July for the years 1985, 1990, 1995, and 2000. The time period on each graph is a little different to avoid periods of very high flow. Variation in the small base flow can not be seen on graphs showing high peak flows.

---

[2]Note that some of the diversion notes list a large water volume per day. These notes should read "ac-ft" not "ac-ft/day."